

Autonomous Wide Aperture Cluster for Surveillance (AWACS) – WHOI Component

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LONG-TERM GOALS

Our long-term goal is to use clusters of Autonomous Underwater Vehicles (AUVs) to detect mobile sound sources using towed hydrophone arrays. We aim to use optimal sampling techniques and inter-vehicle communications to develop long-term surveillance capabilities over large areas in continental shelf and slope regions.

OBJECTIVES

Our objectives for the past year were to develop hydrophone arrays for the REMUS AUV and Webb glider and to test these systems at sea. We did a number of tests over the past year, including participating in the large experiment off New Jersey in conjunction with the Shallow Water Acoustics 06 and Nonlinear Internal Wave Initiative (NLIWI).

APPROACH

During the past year, we have done a number of tests of the hydrophone arrays for the REMUS AUV. These included a December 2005 test in Nantucket Sound as well as the field work off New Jersey. The December test did not include coordinated Physical Oceanographic sampling, but the New Jersey experiment involved a great deal of adaptive sampling. Off New Jersey, we used a towed Scanfish vehicle in addition to the planned use of the AUVs to resolve the shelfbreak front. We coordinated our oceanographic sampling with the continuous glider surveys of S. Glenn at Rutgers University as well as numerical modelers at Harvard University (P. Lermusieax) and Rutgers University (J. Wilkin).

WORK COMPLETED

We have developed a prototype REMUS towed acoustic array which has been used for tracking surface ships and subsurface mobile sound sources (Figure 1) as well as performing bottom geoacoustic surveys. This array allowed us to perform initial, proof of concept experiments in both areas. The most successful effort has been the December 2005 test off Nantucket, MA. This resulted in a number of papers and a Ph.D. thesis by Jason Holmes of Boston University, who was also a guest student at WHOI.

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We have also developed an advanced acoustic array that will replace the prototype system. Due to problems with a vendor, we were forced to develop this array in-house, but we anticipate that this system will be better than the original specifications.

In addition, we have been working on development of concepts for using a combined source and receiver on REMUS to do: 1) bottom surveying, 2) active ASW, and 3) minehunting. This concept has been explored in computer simulations, and will be tested in the field in the near future.

For the physical oceanography, we obtained an outstanding data set in the vicinity of the shelfbreak front during the New Jersey experiment. We sampled on relevant spatial and temporal correlation scales in the front, and used the environmental data to direct adaptive sampling of the acoustic field using OASIS Mobile Acoustic Sources (OMAS).

RESULTS

During the past year we have shown that the REMUS towed hydrophone array is capable of detecting surface ships (Figure 1). Results of this work are in press (Holmes et al., 2006). As shown in Figure 1, the use of synthetic aperture processing results in improved bearing estimates.

During the New Jersey Experiment, the AWACS team did adaptive sampling using oceanographic fields obtained from Scanfish surveys. During the experiment, there was an energetic slope eddy offshore of the shelfbreak front. This was associated with a number of interesting slope water intrusions onto the continental shelf (Figure 3). We are presently analyzing the structure and evolution of the slope water intrusions as well as their impact on acoustic propagation. We also were able to sample the shelfbreak front immediately after the passage of Tropical Storm Ernesto (Figure 4). This data set will provide an important opportunity to relate the offshore slope eddy forcing to the slope intrusions evident well onshore of the shelfbreak.

An important aspect of the experiment was using OASIS Mobile Acoustic Sources to obtain transmission loss data across both the shelfbreak front as well as more ephemeral structures such as filaments of slope water present on the shelf. Despite relatively modest temperature anomalies, the filaments scattered acoustic energy out of mid-depth ducts and had a significant impact on alongshelf propagation of acoustic energy.

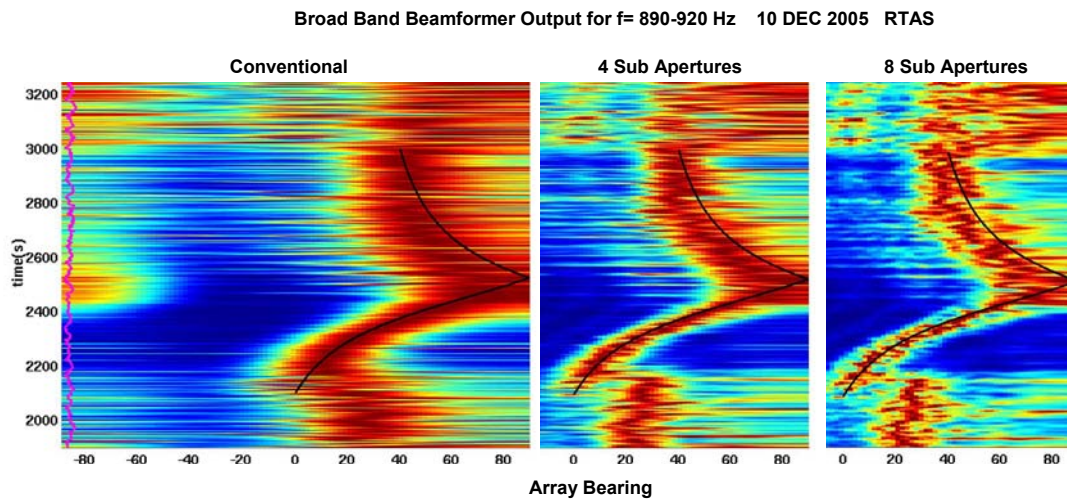


Figure 1. Bearing versus time plot of the Nantucket Ferry made by REMUS acoustic towed array, December, 2005. Adding sub-apertures of the towed array (synthetic aperture processing) resulted in an improved bearing estimate.

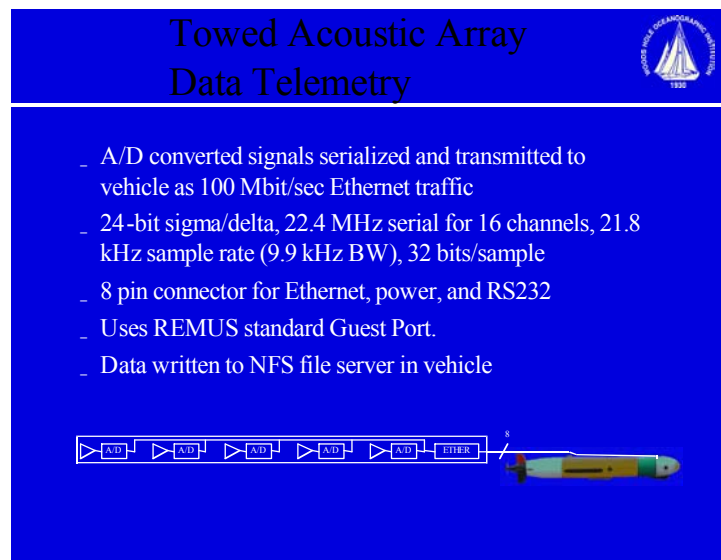


Figure 2: Schematic diagram of the new REMUS acoustic towed array system.

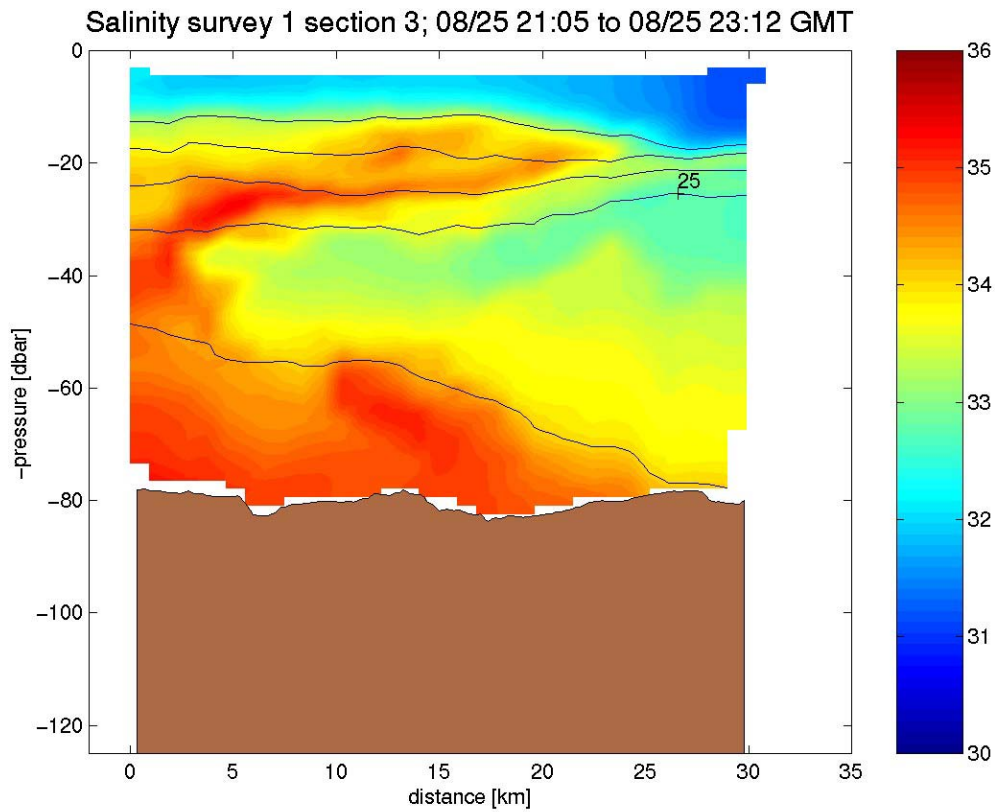


Figure 3- A saline slope intrusion along the 80 m isobath on August 25. The salinity maximum intrusion is centered at 20 m depth, but overlies a deep saline feature. In the upper right hand corner of the section is low salinity surface water which may be related to the Hudson River outflow.

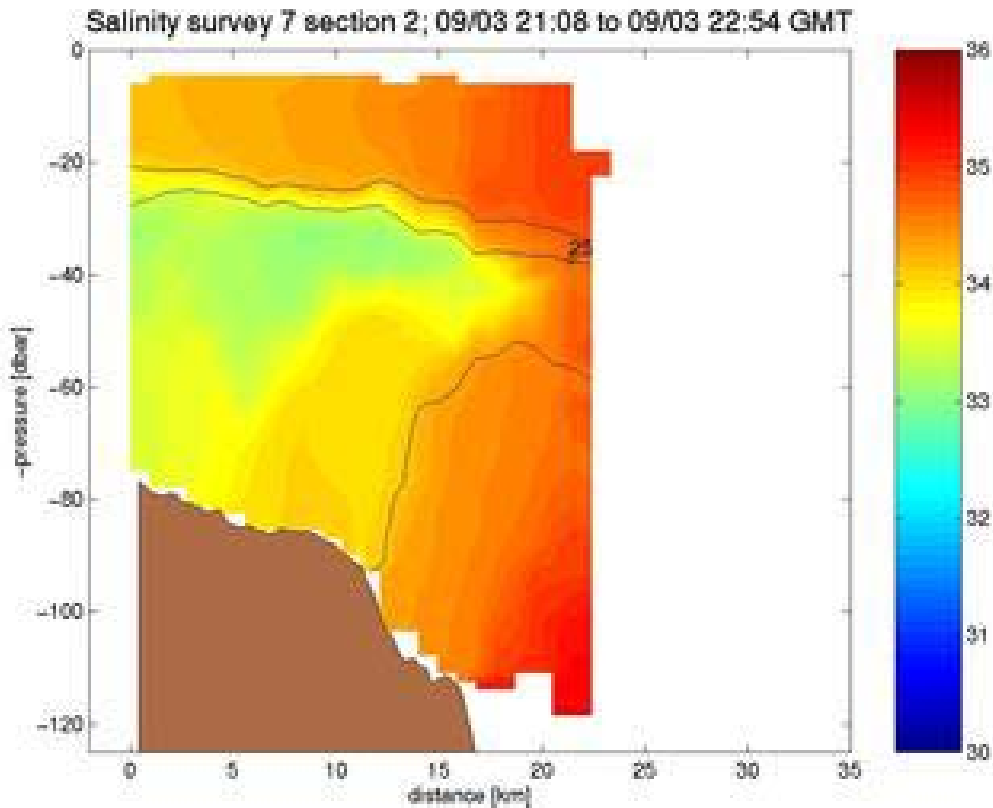


Figure 4- A salinity section from Sunday, September 3, after the passage of Tropical Storm Ernesto. Note the nearly vertical isohalines in both the surface layer as well as the frontal zone.

IMPACT/APPLICATIONS

The demonstration of the feasibility of the use of the REMUS Towed Array provides the basis for continuing system experiments and evaluation of the AWACS concept for cluster surveillance using AUVs.

RELATED PROJECTS

The AWACS project consists of an interdisciplinary team from OASIS, Inc., Adept Systems, Boston University, WHOI the Naval Post Graduate School, Duke and Harvard. Our current bottom geoacoustic measurement effort is related to the ONR-OA investigation of Sound Speed and Attenuation in Multiphase Media. Single path sound transmission measurements from the surface, volume, and the bottom obtained with RTA will provide at-sea measurements required for theoretical and analytical comparisons with the Modified-Biot Theory. Our oceanographic measurement effort is closely integrated with the SW06 LEAR and NLIWI experiments which are being supported by ONR. This work is related to cooperative investigations at Boston University and the Rensselaer Polytechnic Institute, with whom we are sharing resources, results and students.

PUBLICATIONS

(Refereed)

- [1] J. Holmes, W. Carey, and J. Lynch, "Results from an autonomous underwater vehicle towed hydrophone array experiment in Nantucket Sound", in press *J. Acoust. Soc. Am.- EL* (2006).
- [2] E. Sullivan, J. Holmes, W. Carey, and J. Lynch, "Broadband passive synthetic aperture: experimental results." In press *J. Acoust. Soc. Am.- EL* (2006).
- [3] K. Heaney, P. Abbot, G. Gawarkiewicz, T. Duda, and P. Lermusieax, "Non-linear optimization of Autonomous Undersea Vehicle sampling strategies for oceanographic data-assimilation." *Jour. Of Robotics on UnderwaterRobotics*, accepted, (2006).

(Conference Proceedings)

- [1] Jason D. Holmes, William M. Carey, James F. Lynch, Arthur E. Newhall, and Amy Kukulya "An autonomous underwater vehicle towed hydrophone array for ocean acoustic measurements and inversions" Proceedings of IEEE OES Ocean's 05 Europe, June 2005
- [2] Jason D. Holmes, William M. Carey, Allan D. Pierce, James F. Lynch. "Attenuation Characteristics of Sandy Sediments- A simplified Biot approach." Proceedings of the boundary influences in high frequency, shallow water acoustics meeting. University of Bath, UK. Sept. 2005.
- [3] Jason D. Holmes, William M. Carey, James F. Lynch. "Results from the Nantucket Sound autonomous underwater vehicle towed hydrophone array experiment" Proceedings IEEE OES Oceans 06 Boston, September 2006.
- [4] James Lynch, D. Chu, T. Austin, W. Carey, A. Pierce, and J. Holmes, "Detection and classification of buried targets and sub-bottom geoacoustic inversion with an AUV carried low frequency acoustic source and a towed array." Proceedings IEEE OES Oceans 06 Boston, September 2006.

HONORS/AWARDS/PRIZES

Several members of the Oceanographic Systems Laboratory (developers of REMUS) were honored with an Engineering Excellence award from the Museum of Science in Boston for participating in the discovery of the Titanic.